DESIGNING OF PUBLIC VEHICLE DRIVER'S SEAT

By

MOHD SHAHIR BIN YAHYA

Project Paper Submitted to the Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Putra Malaysia in Partial Fulfilment of the Requirement for the Degree of Master of Science

November 2005

In dedication to:

My dear parents, for their affectionate caring;

my beloved wife, Nor Hasnah for her understanding and encouragement; and

my son, Mohamad Adam who has made my life happier.

ABSTRACT

The increasing number of accidents involving buses in Malaysia is a cause of concern for the general population that relies on commercial vehicles. Though there are many factors contributing to this, a seat design, which increases the comfort and alertness of the drivers, may help in reducing fatigue. Since commercial vehicles are imported, their fit with the Malaysian population have been not studied. Ergonomic design of driver's workstation is a necessary component not only for the safety of the population but more so for the driver's safety and health protection. A higher percentage of back and cervical pain has been reported among bus drivers than among workers in non-driving position. In designing a seat, there are many considerations that should be taken into account such as seat reference point, seat height, seat width, lumbar support, and the adjustability range of seat. The objective of this study is to establish the appropriate parameters for designing a bus driver's seat for Malaysian bus drivers by considering their anthropometric dimensions. This study uses qualitative method such as observation and survey to collect the data. The relevant anthropometrics data were used to propose the recommended seat design. The recommended and current seat designs were simulated to analyse the performance of the seat in context of the relative comfort experienced by the bus operators and comparisons were made. Simulation on the existing seat showed that it is not able to accommodate the Malaysian bus driver's population, especially in providing adequate support to operator's back (5th percentile male). The simulation was also used to determine the adjustable ranges of the workstation components so as to accommodate 90% of the male bus driver population.

ABSTRAK

Peningkatan kadar kemalangan yang melibatkan bas di Malaysia adalah perkara yang perlu diberi perhatian oleh pihak yang terlibat secara langsung dengan kenderaan awam. Walaupun, terdapat beberapa factor yang menyumbang kepada kemalangan ini, rekabentuk tempat duduk pemandu memainkan peranan penting dalam meningkatkan tahap keselesaan dan kesihatan pemandu ke arah membantu mengurangkan kadar keletihan di kalangan pemandu. Oleh kerana semua kenderaan awam di Malaysia adalah diimpot, maka kesesuaian tempat duduk berkenaan dengan populasi Malaysia belum pernah dibuat kajian lagi. Justeru, rekabentuk ergonomik bagi stesyen kerja pemandu bas adalah suatu komponen yang sangat diperlukan kerana ia bukan hanya untuk keselamatan pengguna malah perlindungan, keselamatan dan kesihatan pemandu sendiri. Peratus tertinggi dilaporkan bagi kesakitan belakang badan dikalangan pemandu bas jika dibandingkan dengan pekerja yang bukan posisi memandu. Beberapa faktor yang dikenalpasti menyumbang kepada kesakitan belakang-bawah badan antaranya keadaan tempat duduk, getaran, posisi pemandu, dan ketidakcukupan penyokong lumbar. Didalam merekabentuk kerusi pemandu, beberapa aspek perlu diambilkira seperti titik rujukan tempat duduk, ketinggian tempat duduk, lebar, penyokong lumbar dan julat kebolehlarasan ketinggian tempat duduk berkenaan. Objektif kajian ini adalah untuk mewujudkan parameter tempat duduk yang bersesuaian dengan pemandu bas di Malaysia dengan mengambilkira data anthropometri bagi populasi Malaysia. Semua data yang berkenaan dengan tempat duduk sediaada dikumpul dengan menggunakan kaedah qualitatif seperti pemerhatian dan soal selidik. Berpandukan kepada data anthropometri bagi pemandu bas di Malaysia, ukuran rekabentuk tempat duduk yang

baru dicadangkan. Hasil daripada simulasi yang dijalankan, menunjukkan bahawa rekabentuk kerusi pemandu sediada tidak dapat memenuhi keperluan populasi Malaysia terutamanya di dalam memberikan penyokong yang cukup pada bahagian belakang badan pemandu (5 percentil lelaki). Simulasi juga digunakan dalam menentukan julat pelarasan komponen pada stesyen kerja supaya ianya dapat memenuhi keperluan 90 peratus daripada populasi pemandu lelaki.

ACKNOWLEDGEMENT

All the praise to Allah the Al-Mighty for his blessing and benevolence.

The author wishes to express his sincere gratitude and appreciation to the numerous individuals whose have contributed towards the completion of this final project:

- To my supervisor: Associate Professor Dr. Rosnah binti Mohd. Yusuff, for her invaluable advise, supervision and assistance;
- To Jabatan Perkhidmatan Awam (JPA) and Kolej Universiti Teknologi Tun Hussein Onn (KUiTTHO), for providing financial supports throughout the duration of the study;
- To Department of Community Health, Faculty of Medicine and Health, UPM, for providing the Malaysian bus driver's anthropometry data.
- To all the respondents of the survey, for their cooperation in answering the questionnaire.
- To all other individuals that directly and indirectly involved in this research.

Thank you for all your contributions. May Allah bless you all.

This project paper submitted to the Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Putra Malaysia and has been accepted as partial fulfilment of the requirements for the degree of Master of Science (Manufacturing System Engineering). The members of the Supervisory Committee are as follows:

Rosnah Mohd. Yusuff, PhD.
Associate Professor
Department of Mechanical and Manufacturing Engineering
Faculty of Engineering
Universiti Putra Malaysia
(Main Supervisor)

Megat Mohamad Hamdan Megat Ahmad, PhD.
Associate Professor
Department of Mechanical and Manufacturing Engineering
Faculty of Engineering
Universiti Putra Malaysia
(Examiner)

DECLARATION

I hereby declare that the project paper is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

MOHD SHAHIR BIN YAHYA

Date: 30th November 2005

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS/NOTATIONS/GLOSSARY OF TERMS

AHP	-	Accelerator-Heel-Point
CAD	-	Computer Aided Design
DEP	-	Design-Eye-Point
E	-	Scaling factor
HRP	-	Heel-Reference-Point
RSIs	-	Repetitive Strain Injuries
RULA	-	The Rapid Upper Limb Assessment
SIP	-	Seat-Index-Point
SRP	-	Seat-Reference-Point
X	-	Sample x
Y	-	Sample y

CHAPTER 1

INTRODUCTION

1.1 Introduction

The buses are one of the public transportation, which has been widely used in any country. It is the cheapest mean mode of transportation in order to simplify the journey of people to go anywhere. Normally the average time for bus operation per day is 8 hours. That is mean, the bus drivers most probably will expose to health problem because of prolonged driving.

Bus driving is characterized by psychological and physical stresses. Most severe are the stresses of traffic in big cities, because of the heavy traffic and frequent stops. In most transit companies, the drivers must, in addition to driving responsibilities, handle tasks such as selling tickets, observing passenger loading and unloading and providing information to passengers. Psychological stresses result from the responsibility for the safe transport of passengers, scant opportunity to communicate with colleagues and the time pressure of holding to a fixed schedule. Rotating shift work is also psychologically and physically stressful. Ergonomic shortcomings in the driver's workstation increase physical stresses (Alfons Grösbrink and Andreas Mahr, 1998).

There are many factors that contribute to the higher than normal morbidity and mortality rates of transit bus operators. The previous study was identifying three main disease categories: cardiovascular disease, gastrointestinal illness and musculoskeletel problem. The most prevalent of this health problem are musculoskeletel, relating to neck and back pain (Patterson, 1986). Frequent awkward postures, muscular effort, vibration and shock, as well as whole body vibration exposure and prolonged sitting in a constrained position all contribute to overworking the lumbar spine and its supportive structures, causing low back pain (Brovenzi, and Zadinim, 1992).

1.2 Background of the problem

Musculoskeletal disorders are among the leading causes of occupational injury and disability, with back pain the most common reason for the filing of workers' compensation claims. Back pain accounts for about one fourth of all claims and for about 40 percent of absences from work. In the United States, in 1990, the cost of back pain was estimated between $50 billion to $100 billion. (Saporta, 2000)

There is strong evidence of an association between musculoskeletal disorders, workplace physical factors, and non-work related characteristics. Non-work related characteristics include physical fitness, anthropometric measures, lumbar mobility, physical strength, medical history, and structural abnormalities of the individuals. Workplace physical factors include heavy physical work, lifting and forceful movements, awkward postures, whole-body vibration, and static work postures. Static work postures of prolonged standing, sitting, and sedentary work are isometric positions where very little movement takes place. These postures are typically cramped or inactive and cause static loading on the muscles. (NIOSH, 1997)

Several studies have investigated back pain among professional drivers. The occupational physical factors of postural stress, muscular effort and long term exposure to whole-body vibration were consistently associated with driving motor vehicles for extended periods of time (Bovenzi et al., 1992). Anderson, (1992) found that a higher percentage of reported back and cervical pain among bus drivers than among workers in non-driving positions.

Other studied was found male workers who drove for more than 50 percent of their work time were approximately three times more likely to develop an acute herniated lumbar disc than those who drove less frequently (NIOSH, 1997). Magnusson, (1996), reported higher rates of low back pain (60 percent) and proportionally more work loss among bus drivers than truck drivers.

In Malaysian situation, the previous studies (Wan, 2005) showed that, most of the Malaysian bus driver's complaint that they have an experience of lower back pain while driving. 63.2% of them (n=308 respondent) complaint on it as shown in figure 1.1.

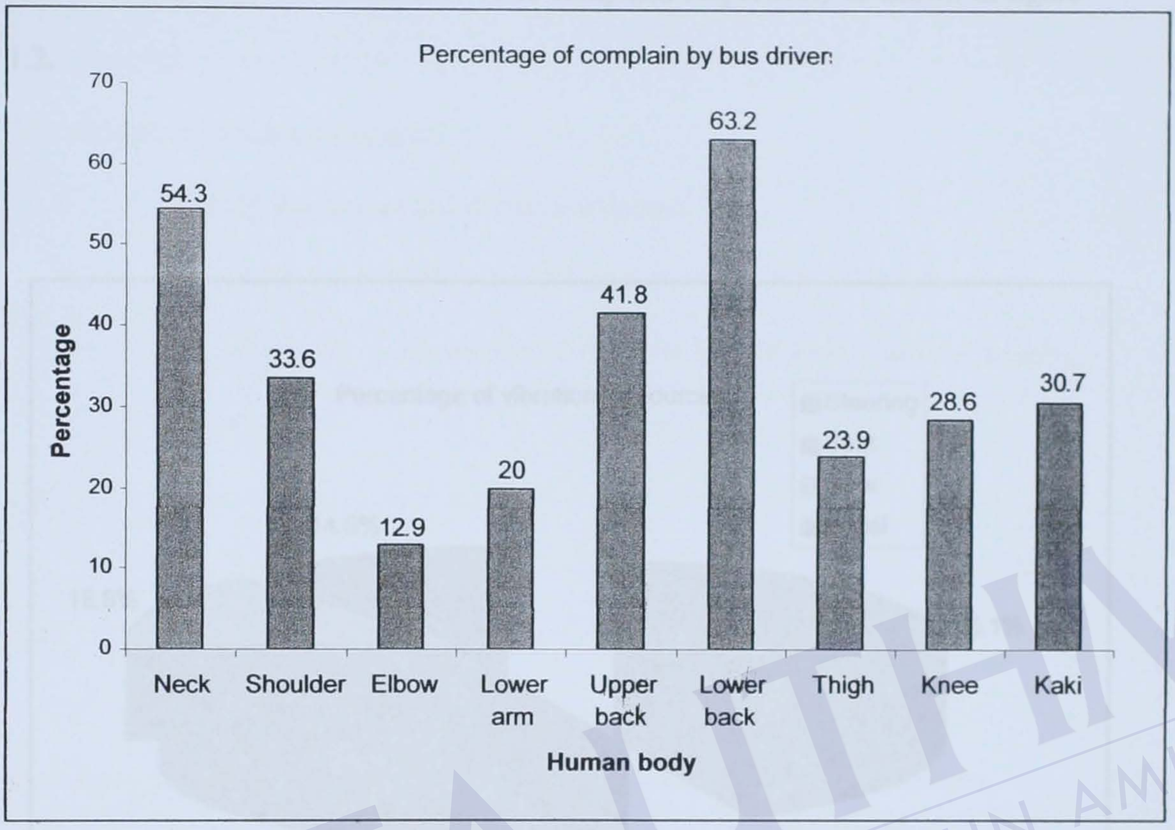

Figure 1.1: Percentage of respondent that complain of pain in their body

There are several factor that can caused the lower back pain such as the seat condition, vibration, posture of drivers and so on. The most factor that contributed to back pain is the seat condition, which is not enough support at lumbar. Lumbar support plays an important role to make the drivers feel comfortable while driving. Neck pain is the second highest of complaint. About 54.3% of respondent have an experience on neck pain. This is because there is no headrest provided at the current seat.

From the study also, they found that another factor that contributed to discomfort of the seat is the vibration. The vibration was identified came from steering, seat, gear and pedal. The highest vibration reported came from steering then followed by the seat that contribute 56.1% and 39.6 % of complaint respectively as shown in figure 1.2.

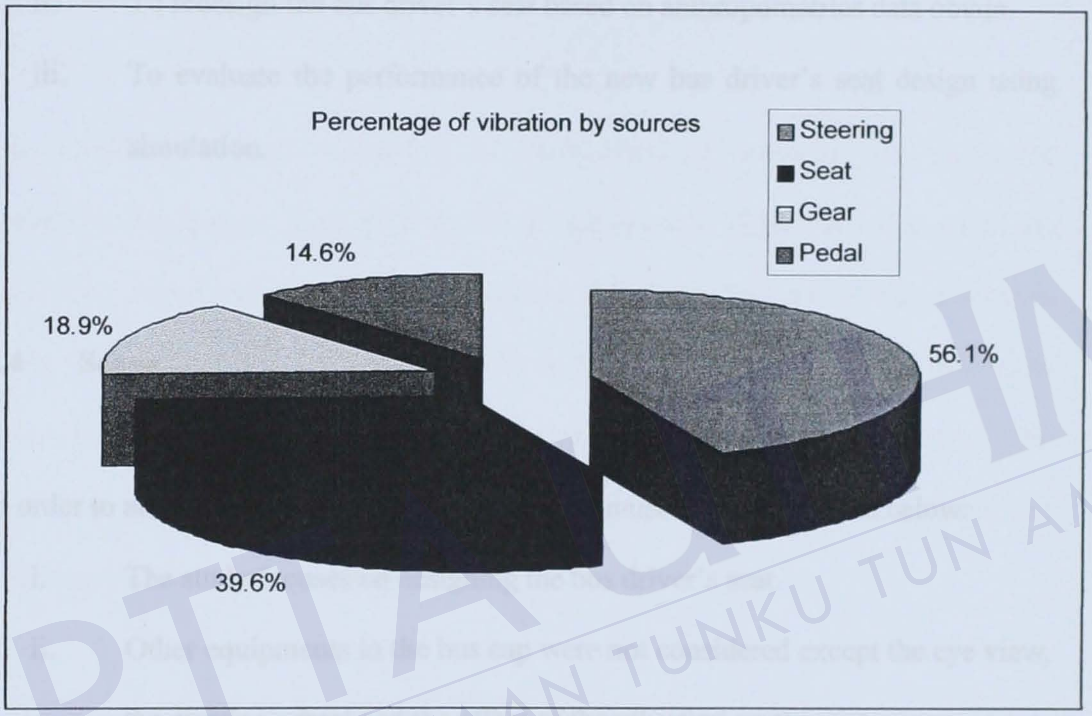

Figure 1.2: Percentage of vibration by the sources.

Ergonomic design of the driver's workstation is a necessary component of driver safety and health protection. From the previous studied show that, there is a need of modification or redesigning the seat with considering the ergonomic approach in order to reduce the back pain, neck pain and vibration level that contribute to health problem among Malaysian Bus drivers particularly that can interfere with productivity.

1.3 Objective

The objectives of this project are:

i. To study the current bus driver seat design.

ii. To redesign the bus driver's seat based on anthropometrics data obtain.

iii. To evaluate the performance of the new bus driver's seat design using simulation.

1.4 Scope

In order to accomplish this project, the limitation must be considered as below:

i. The study focuses on designing the bus driver's seat.

ii. Other equipments in the bus cap were not considered except the eye view, the steering wheel and the effect of the vibration on the seat.

iii. The pedal and the control panel board are assumed to be in fixed condition.

1.5 Significance of the study

This study will help the bus drivers to reduce back pain and neck pain. The seat that provided with proper support, proper adjustable height, recline of seat back, suspension and so on, will make the driver feel comfortable while driving the bus. It also help in increasing the drivers motivation, reduced the medical certificate (mc) among bus drivers, reduced the accident rate involving buses, increase the bus drivers performance and at last will increase the company productivity.

1.6 Summary

This chapter is about explanation of background of problem particularly for Malaysian bus drivers. Then, followed by the statement of objective and scope of the study that considered in order accomplishing the study. The last of this chapter is about the significant of the study in order to help all the Malaysian bus drivers to reduce the back pain and neck pain that most of Malaysian bus drivers' problem. The next chapter is a presenting a literature review of relating to the seat features and their consequence to the human body.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

One of the most important aspects of designing vehicle systems is creating an interior compartment that is accommodating, or meets the needs of the customer population that the vehicle is targeting. If the design does not fully meet the requirements of the customer, it will probably fail to realize its full market potential (Pugh, 1990). When employing human factors and ergonomics techniques, the objective is to design the environment to fit the capabilities and limitations of the customer by (Cushman, and Rosenberg, 1991):

i. Identifying the target customer, and fully recognizing their needs and requirements for comfort, safety, and accommodation through understanding their physical, cognitive, and behavioural characteristics.

ii. Accommodating the entire range of the target customer population by designing the interior compartment to address their needs and requirements given their characteristics.

For designing the seat, it should be such that it encourages the occupant to adopt a good posture and discourages poor postural habits. The design of the seat as well as the surrounding environment should allow the occupant to make frequent minor postural changes without hindrance (Lusted, 1994). The bus drivers especially, often sit in a cramped space under conditions such that even with a normal spine it is difficult to be comfortable, especially if required to sit for several hours at a time.

The purpose of work seating is both to take the weight off the feet and to provide a stable base from which to perform work (Branton, 1969). The seat should allow for relaxation of the muscles not required for the task as well as intermittent relaxation of those that are. Although it is important to evaluate a seat according to anthropometrics dimensions, these should be considered a starting point only. Both behavioural and subjective measures must be included in any evaluation of seats (Branton, 1969).

2.2 Anthropometrics data

Anthropometry is the branch of the human sciences that deals with body measurements: particularly with measurements of body size, shape, and strength and working capacity. Anthropometrics is a very important branch of ergonomics. It stands alongside (for example) cognitive ergonomics (which deals with information processing), environment ergonomics, and a variety of other identifiable sub disciplines, which progress towards the sane overall end (Pheasant, 2001).

Anthropometric data are used in design standards for new systems and in the evaluation of existing systems in which there is a human-equipment interface. The purpose of the data is to ensure that the worker is comfortable and efficient in performing work activities and in the use of the equipment (Waller. and Green. 1997).

Generally the use of anthropometrics data is based on three principles (Sander. 1987):

i. Design of extreme individuals

In designing the product, the aspect of can accommodate the population must be considered. In some circumstances when a specific design dimension or feature is limiting factor that may restrict the use of the facility for some people, that limiting factor can dictate either maximum or minimum value of the population variable of the characteristics in question.

The maximum value, or using the 95^{th} percentile in anthropometry is an appropriate design strategy if the design features should accommodate all people (e.g. designing heights of the doorways). On the other hand, the minimum value or the 5^{th} percentile is an appropriate design strategy if a given minimum value is the limitation factor which can accommodate all population (e.g. designing distance of control button).

ii. Designing for adjustable range

In designing the adjustable features of equipment or product, an adjustable range covering from 5^{th} percentile to the 95^{th} percentile is frequently used. The use of such range is relevant if there are technical problems in trying to accommodate the very extreme cases to cover 100% of the population.

iii. Designing for the average

Designing for the average or the 50th percentile means that half of the population conceivably could be excluded. Therefore the use of average value as a design criteria for equipment or facilities should be avoided unless for legitimate reasons where it is not appropriate to use extreme values or feasible to provide for an adjustable range.

2.2.1 How to gets missing data

Ratio scaling is one technique for estimating data from known dimensions. It relies on the assumption that, though people vary greatly in size, they are likely to be similar in proportions. (Kroemer, 2003)

Scaling factor E was calculate from:

$$E = d_x / D_x \tag{2.1}$$

Since the basic assumption is that the two samples are similar in proportion, the same scaling factor E applies to both samples X and Y:

$$E = d_x / D_x = d_y / D_y \tag{2.2}$$

with

$$E = d_y / D_y \tag{2.3}$$

Then, the missing data desired by calculate

$$d_y = E * D_y \tag{2.4}$$

REFERENCES

Alfons Grösbrink and Andreas Mahr (1998), Ergonomics of Bus Drivers, Transport Industry and Warehousing. *In* Encyclopaedia of Occupational Health and Safety, 4th ed. Geneva: International Labour Office, Vol. 3. Pt XVII.

Anderson, R. (1992), "The Back Pain of Bus Drivers – Prevalence in an Urban Area of California", Spine 17:1481.

Branton, P. (1969), "Behaviour, body mechanics and discomfort", *Ergonomics* 12, 316-327.

Brovenzi, M. and Zadinim A. (1992), "Self-Reported Low Back Symptoms in Urban Bus Drivers Exposed to Whole Body Vibration", Spine, vol. 17, no. 12, pp. 1048-1059.

Brown, Alan S. (1999), "Role Models: Virtual People Take On the Job of Testing Complex Designs," Mechanical Engineering, p. 44.

Case, K., Poster, J.M., Bonney, M.C. (1990), "SAMMIE: A Man and Workplace Modeling System," in Karwowski,W.,Genaidy,A.M., and Asfour,S.S. (Eds.), Computer-Aided Ergonomics, Taylor & Francis, London.

Chaffin, D.B. and Andersson, G. (1991), Occupational Biomechanics, John Wiley and Sons.

Chaffin, D.B. (2001), "Digital Human Modeling for Vehicle and Workplace Design", Society of Automotive Engineers (SAE), Inc., USA.

Courtney, A.J. and Wong, M.H., (1985)," Anthropometry of the Hong Kong male and the design of bus cabs", Applied Ergonomics, Hong Kong, p. 259-266.

Courtney, A.J. and Evans, W.A. (1987), "A Preliminary Investigation of Bus Cab Design for Cantonese Drivers", Journal of Human Ergology, vol. 16, pp. 163-171.

Cushman, W.H. and Rosenberg, D.J. (1991), "Human Factors In Product Design", Elsevier, Amsterdam.

Daimler Chrysler, (1999), "SAE Paper No. 1999-01-3736", Society of Automotive Engineers, Warrendale, Pa.

Diffrient, N., Tilley, A.R., and Harman, D. (1981), "Human Scale 7/8/9, Cambridge, Ma, The MIT Press.

Drury, C. G. and Coury, B.G. (1982), "A methodology for chair evaluations" *Appl Ergon* 13, 195-202.

Eastman Kodak Company (1983), "Ergonomic Design for People at Work", Volume I, Chapter VI, Section A, Anthropometric Data in Design,Van Nostrand Reinhold Company.

Gilmore, B.J., Bucciaglia, J., Lowe, B. You, H., and Freivalds, A. (1997), "Bus Operator Workstation Evaluation and Design Guidelines", TCRP Report F-4, Transportation Cooperative Research Program (TCRP), Transportation Research Board.

Hammings, K.R.,(1974), "Proceedings of the Institution of Mechanical Engineers, 188, 27-24. Commercial-vehicle cabs: design for packaging, access and visibility.

Hubbard, R.P. et al., (1993), "New Biomechanical Models for Automobile Seat Design", SAE 930110.

Kroemer, K.H.E, (2003), "Engineering Anthropometry: Principle of Work Design".

Levy, B.S. and Wegman, D.H., (1995), "Occupation Health – Recognizing and Preventing Work-Related Disease", Third Edition, Little, Brown, and Company.

Lueder, R. (1996), "A proposed RULA for Computer Users". Preceedings of the Ergonomics Summer Workshop, UC Berkeley Center for Occupational and Environmental Health Continuing Education Program, San Francisco.

Lusted, M., Healey, S., and Mandryk, J.A., (1994), "Evaluation of the seating of Qantas flight deck crew", Applied Ergonomics, 25(5), pp. 275-282

Magnusson, M., Pope, M.H., Wilder, D. G., Areskoug, B.,(1996), "Are Occupational Drivers at an Increase Risk for Developing Musculoskeletal Disorder", Spine 21:710-717,

National Institute for Occupational Safety and Health (NIOSH), (1997), *Musculoskeletal Disorders and Workplace Factors*, U.S. Department of Health and Human Services

Patterson, P.K., Eubanks, T.L. and Ramseyer, R. (1986), "Back Discomfort Prevalence and Associated Factors Among Bus Drivers". AAOHN Journal, Vol. 34, No. 10, pp. 481-484.

Pheasant, S., (2001), Bodyspace: Anthropometry, "Ergonomics and the Design of Work", Taylor & Francis Ltd., London.

Philippart , N.L., Kuechenmeister, T.J., Stanick, J.M. (1986), "Truck Driver Selected Seat Position Mode", SAE 861131, Warrendale, PA, Society of Automotive Engineer.

Pugh, S.,(1990), "Total Design", Addison Wesley Publishers Ltd., England.

Rosnah M.Y., Wong O.O., (1995), Development Of An Anthropometric Dimensions Database For The Malaysian Population, ASEAN, J. Sci. Technology. Development. 12(1).

Ryan, P.W. and Springer, W.E.,(1969) "Cockpit Geometry Evaluation Final Report," Vol. V, JANAIR Report 69105, Office of Naval Research, Washington, D.C.

Sander, M.S., (1987), Applied Anthropometry and Work Space: Human Factors In Engineering and Design, McGraw-Hill International Editions, Sixth Edition, New York, pp. 331-361.

Saporta H. (2000), "Durable Ergonomic Seating for Urban Bus Operators", Tri-Country Metropolitan Transportation District of Oregon.

Waller, P.F. and Green, P.A.(1997), Handbook of Human Factors and Ergonomics, Chapter 59 - Human Factors in Transportation, John Wiley and Sons, Inc.

Wan C.Z.W.H., Hamiraj A.F., Shamsul B.M.T., Rosnah M.Y., Nasaruddin A.A., Juliana J., Rosnan H., and Yunus. A. (2005), "Anthropometrics Measurements Of Malaysian Commercial Vehicle Bus Drivers For Malaysian Bus Seat Design", UPM Serdang, Malaysia.

Thompsonn, Deporah D., (2001): Digital Human Modeling for Vehicle and Workplace Design: The Determination of the Human Factor/Occupant Packaging Requirements for Adjustable Pedal System. Society of Automotive Engineers (SAE), Inc., USA.

Transportation Research Board, (1997), Final Report: Bus Operator Workstation Evaluation And Design Guidelines, The Pennsylvania Transportation Institute.